

# **NAGW-2114: Final Technical Report**

The above-mentioned award was extended at no-cost funding through March 31, 1995 in order to complete analysis of AIRSAR/TOPSAR data acquired over the erosional escarpment of southeast Australia in September, 1993. The results of that work were reported in a conference proceedings volume (Weissel, 1997). The text of Final Technical Report for NAGW-2114 is taken from that published report.

## **AIRBORNE RADAR INVESTIGATION OF ESCARPMENT EROSION ACROSS THE NEW ENGLAND SECTION OF THE SOUTHEAST AUSTRALIAN CONTINENTAL MARGIN**

Jeffrey K. Weissel  
Lamont-Doherty Earth Observatory of Columbia University  
Palisades, NY 10964  
U.S.A.

### **Introduction**

Many rifted or passive continental margins feature a seaward-facing erosional escarpment which abruptly demarcates deeply weathered, low relief, interior uplands from a deeply incised, high relief coastal zone (Ollier 1982, 1985; Weissel, 1990). It is generally accepted that these escarpments originate at the time of continental rifting and propagate inland through the elevated rift flank topography at rates on the order of 1 km/Myr over the course of a margin's history (e.g., Ollier, 1985; Gilchrist and Summerfield, 1990; Seidl et al., 1996; Summerfield, 1991; Weissel, 1990). Considering the length of passive margins worldwide and an average rift flank plateau height of several hundred meters, it is clear that sediment eroded from passive margins is an important component of the mass flux from continents to oceans through geologic time. The overall goal of the research reported here is to develop a quantitative understanding of the kinematics of escarpment propagation across passive margins and the underlying geological processes responsible for this behavior.

Plateau-bounding escarpments in general exhibit two basic forms depending on the direction of surface water drainage on the plateau interior relative to the escarpment (Schmidt, 1987). Where surface water flows away from the escarpment, the escarpment takes the form of subdued embayments and promontories, such that its overall trend remains fairly straight as it evolves with time. Where upland streams flow across the escarpment, it takes the form of dramatic, narrow gorges whose heads appear to propagate up the plateau drainage systems as large-scale knickpoints. From work on the Colorado Plateau, Schmidt (1987) noted that the Colorado River is located much closer to the Grand Canyon's south rim, a drainage divide escarpment, than to the north rim, which is a gorge-like escarpment. The main implication is that the gorge-like form might be associated with higher long-term average erosion rates compared to the drainage divide escarpment type.

The continental margin of southeast Australia is a good place to study the rate and pattern of escarpment erosion because its rifting history is well known (e.g., Weissel and Hayes, 1977), and, as noted by Young and McDougall (1993), tectonic activity during its post-rift history has likely been minimal and its maritime, southern hemisphere location has buffered the region from the effects of Late Cenozoic climate change. The New England Tableland section of the margin (Fig. 1) is especially attractive because the gorge-like form of erosional escarpment is clearly expressed in the landscape (Ollier, 1982; Weissel, 1990; Seidl et al., 1996), and the escarpment is currently eroding through only two bedrock lithologies (granites and fine-grained metasediments of Late Paleozoic age).

## **Airborne radar data**

In September 1993, a 60 km-long airborne synthetic aperture radar (AIRSAR) and radar interferometry (TOPSAR) transect was flown along an azimuth of  $158^{\circ}$  –  $338^{\circ}$  across the erosional escarpment bounding the New England Tableland of New South Wales. The center of the transect lies about 50 km due east of the city of Armidale (Fig. 1). Radar data from these flights was processed by the Jet Propulsion Laboratory (JPL) in Pasadena, California. Among the data products received to date from JPL are: 3-band (C-VV, L-HH, P-HH) AIRSAR imagery from the synoptic processor, and more recently, four approximately 10 km x 10 km TOPSAR frame products which include 10 m resolution interferometric Digital Elevation Models (DEMs) and associated 3-band AIRSAR imagery. Three of the DEMs form a mosaic across the escarpment, while the other is located on the Tableland in an area also covered by a 20 m DEM derived from a SPOT stereo pair (Fig. 1). The AIRSAR/TOPSAR data will be integrated with the existing SPOT multispectral imagery and SIR-C/X-SAR data coverage of the region. These data form the digital topographic and multispectral imagery foundation for the study of the rate and pattern of escarpment erosion in the New England Tableland region currently underway (Seidl et al., 1996).

## **Preliminary Data Evaluation**

Although the TOPSAR data products have been available for a relatively short time, some preliminary evaluation can be made at this stage. Figure 2 shows a grey-scale image of topographic gradient for the TOPSAR DEM from frame TS-90 (Fig. 1), which is the frame that crosses the escarpment. Topographic height ranges from about 1200 m on the Tableland down to about 250 m in the river valley below the escarpment. The gradients in Figure 2 were computed as the scalar product between the normal to the topographic surface and the unit vector to an artificial sun at an elevation of  $60^{\circ}$  and an azimuth of  $75^{\circ}$ .

The first thing to note in Figure 2 is the distribution of “NULL” patches, which are groups of cells in the DEM where height could not be determined. Because the direction of illumination is from the left, the look angle of the radar increases from about  $24^{\circ}$  to about  $64^{\circ}$  from left to right across frame TS-90. The NULL patches tend to be concentrated on steep slopes facing the radar in the near slant range (left-hand third of the image), and on steep slopes facing away from radar for large slant range (Fig. 2). This pattern of NULL patches is

typical of the New England Tableland TOPSAR DEMs, but is more pronounced in the frames over rugged terrain across and below the escarpment (TS-90 and TS-103, Fig. 1). The most likely cause for the pattern of NULL patches is radar lay-over in the near slant range and shadowing in the far slant range.

Also of note in Figure 2 is fine-scale texture in the DEMs imparted by backscatter from the eucalyptus forest canopy. This canopy effect is more apparent in DEMs covering portions of the Tableland where stands of forest are juxtaposed against land cleared for grazing (frames TS-91 and TS-102, Fig. 1). In fact, systematic height offsets can be discerned in these DEMs where forest gives way abruptly to cleared land across fence lines. In addition, stands of trees cause radar shadows at the extreme far slant range in the TOPSAR imagery. C-band radar apparently will not penetrate far into eucalyptus forest canopy even during the dry weather conditions that prevailed during data collection. On one hand the trees introduce systematic bias into the interferometric DEMs, but on the other, forest volume could apparently be calculated given some ground truth on tree height.

Two technical problems have arisen thus far with the TOPSAR frame processor products furnished by JPL for the New England Tableland site. First, all the C-band VV polarization backscatter data have truncated histograms of values. Apparently, the full range of amplitudes in the C-VV data is greater than can be accommodated with the INTEGER\*2 format used by JPL. As a result, grey scale images of the truncated C-VV data appear to have too much contrast. Second, the value assigned to the NULL cells in the interferometric DEM for frame TS-103 is right in the middle of the histogram of *bone fide* data value. As a result, NULL values cannot be easily distinguished from true height values in the resulting images. This stands in contrast to the situation for TS-90 (Fig. 2) where the NULL cells, set to white, are clearly distinguishable from the real data. Both of these technical problems with the TOPSAR data for the New England Tableland site can be easily remedied in principle.

## Summary

Although evaluation of the TOPSAR frame processor data for the New England Tableland site is still at an early stage (the L- and P-band polarimetry data, for example, have not yet been imaged), a few observations can be made about the utility of high-resolution airborne radar data in studies of erosional escarpments at passive margins. First, the extensive patches of empty DEM cells caused by radar lay-over and shadowing in rugged terrain (e.g., Fig. 2) could be reduced by employing multiple radar look directions. Second, canopy backscatter produces systematic height errors in interferometric DEMs. This is undesirable if the goal of the DEM analysis is, for example, to calculate slopes for determining flow paths of surface runoff. However, the DEM does contain information about forest volume that can be extracted given some calibration or ground truth data on tree heights.

## References

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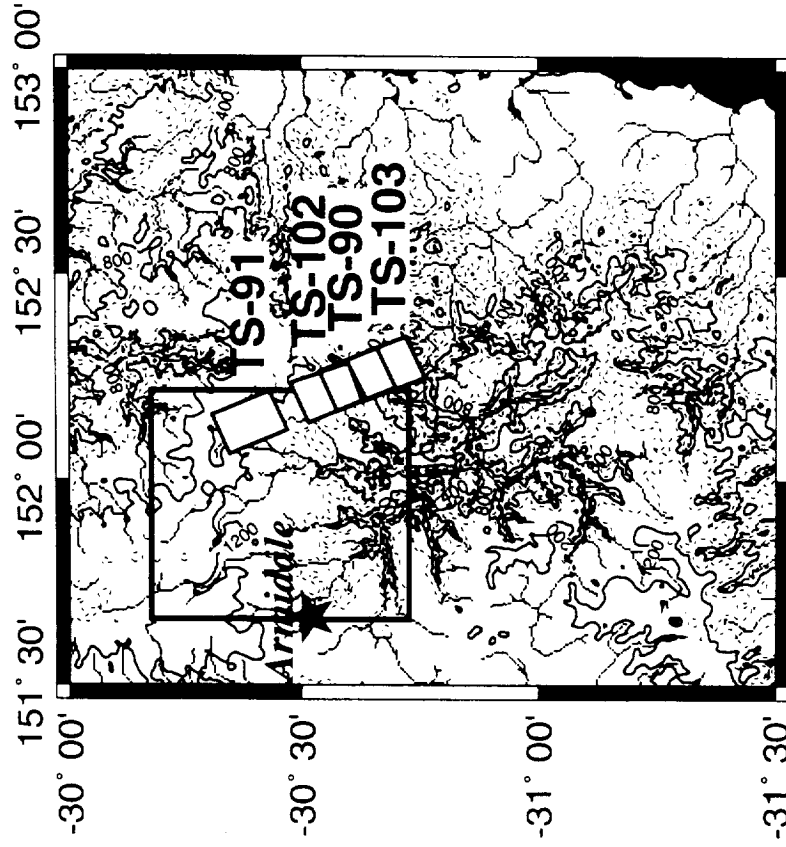


Figure 1. Topographic map of the New England Tableland section of the southeast Australian continental margin contoured at 200 m intervals and labeled every 400 m. Locations of the TOPSAR frame products are indicated by the labeled white boxes, and the location of the SPOT-derived DEM by the larger, unfilled box. Principal streams are shown and the offshore area is colored black.

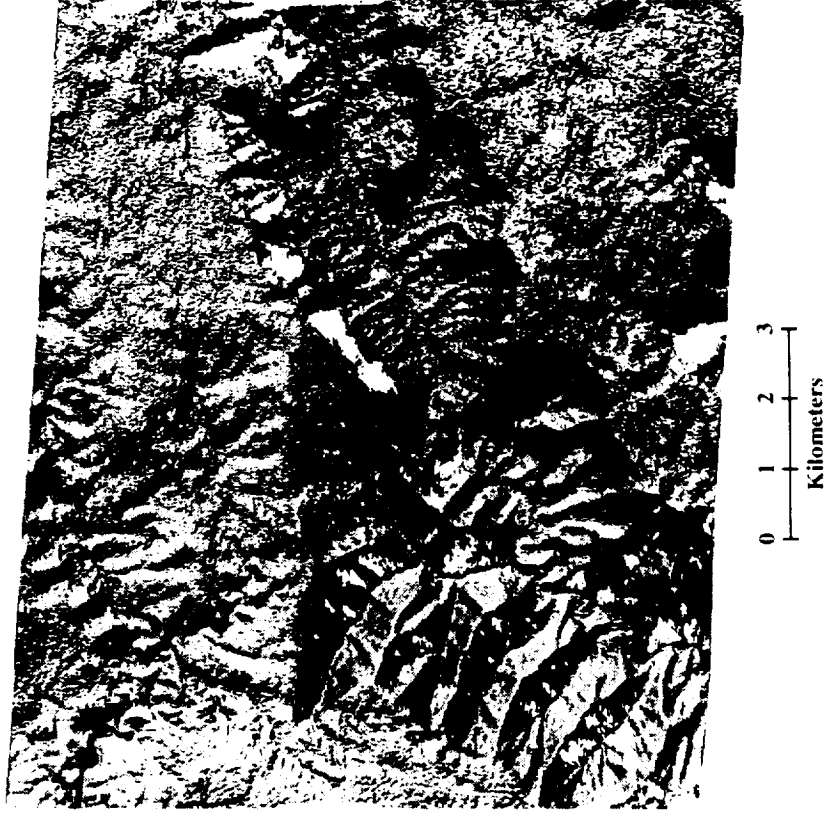


Figure 2. Grey scale image of topographic gradient along an azimuth of  $75^{\circ}$  determined from the interferometric DEM for frame TS-90 (Fig. 1). See text for discussion.